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# Health Effects of Air Pollution: PRC Progress and Regional Challenges in Asia

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# Outline



## CONTENTS

- 1. Background:** health effects of air pollution
- 2. Clean air action in PRC:** an quasi-experimental health intervention
- 3. Health impact assessment:** enlarged benefits & lowered inequality
- 4. Air quality challenges in Asia:** Climate-related & anthropogenic pollution

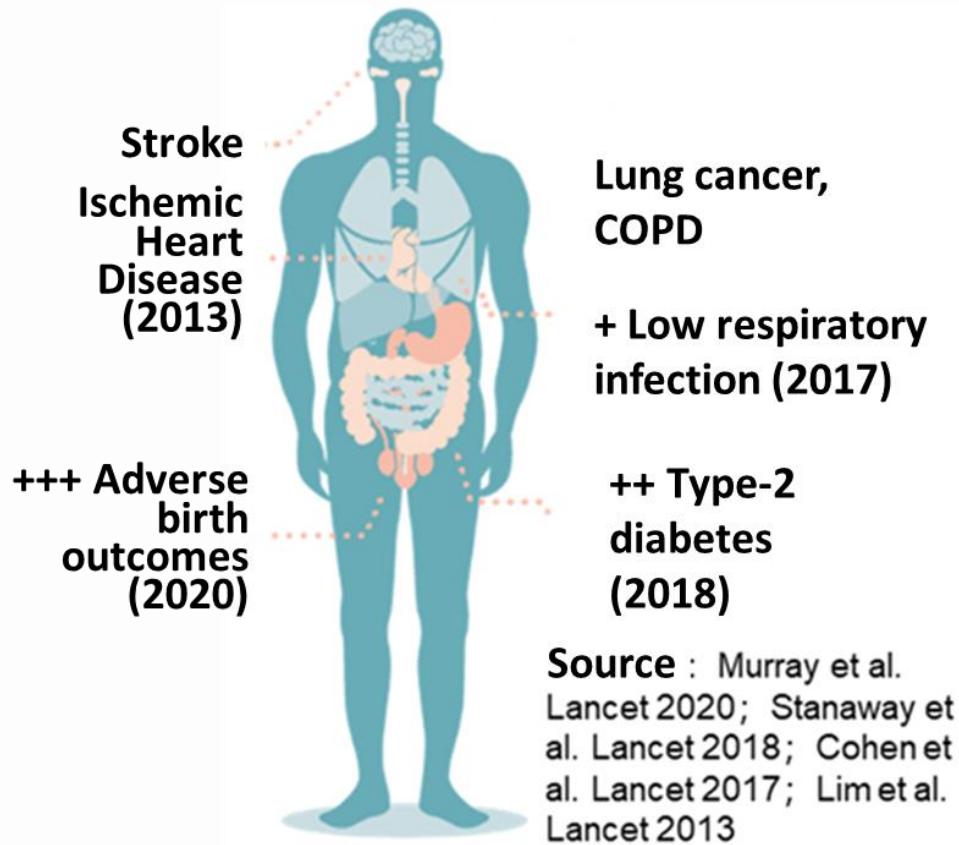


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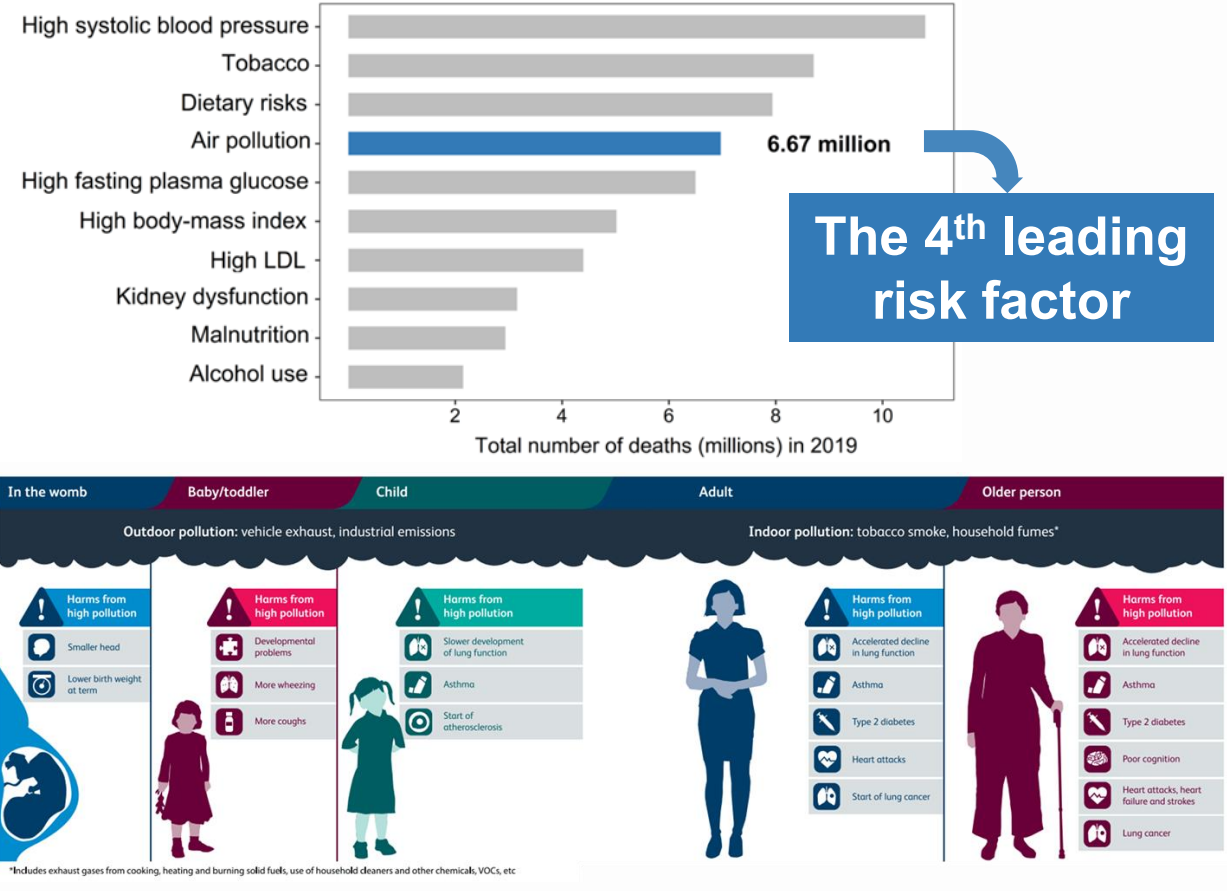
# Background: health effects of air pollution

# The lifelong course effects of air pollution

## Major outcomes



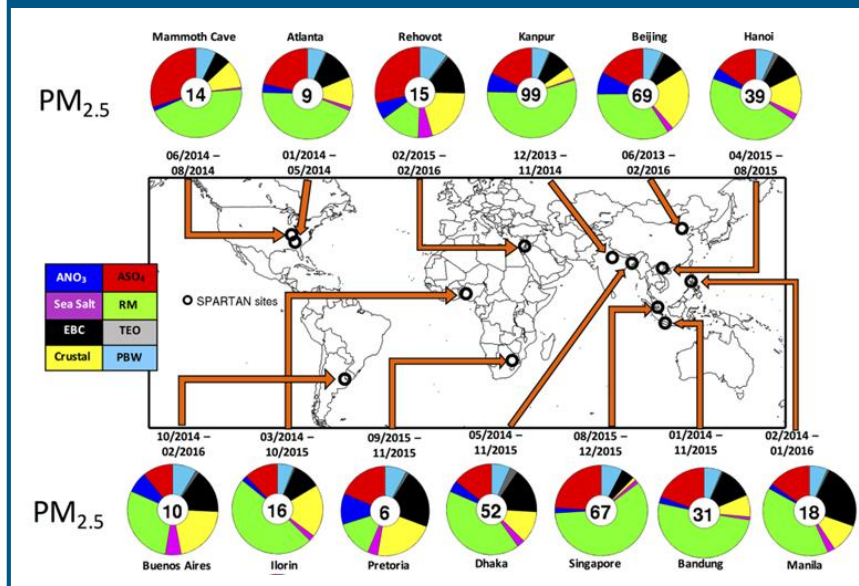
## Global burden of air pollution



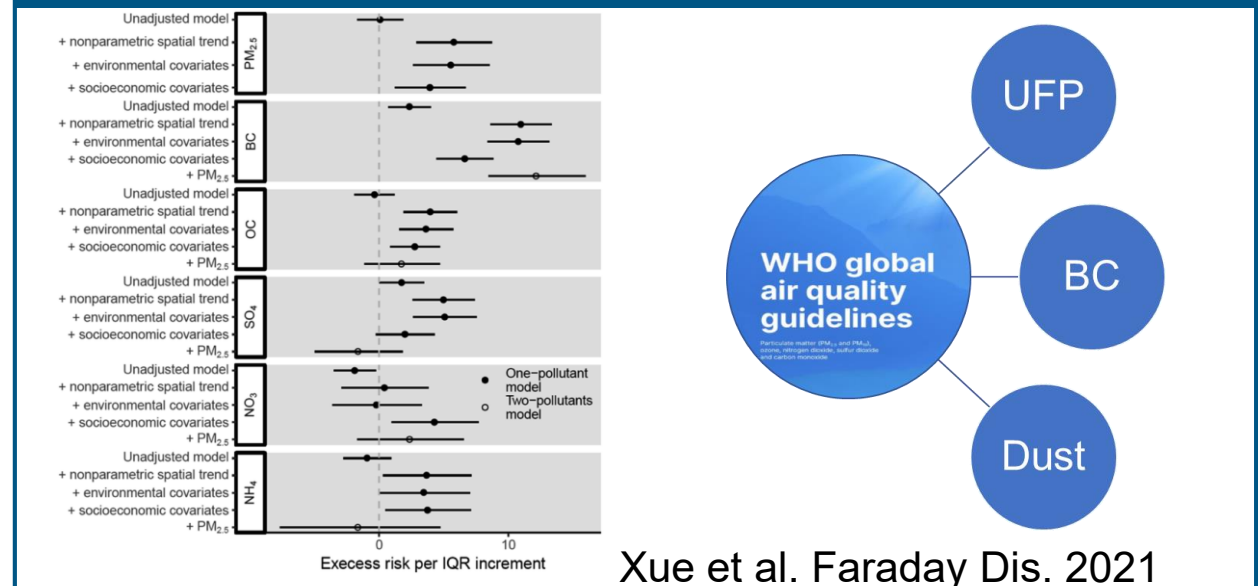
Global Statement of Air 2020; Every breath we take: the lifelong impact of air pollution, 2016

# Unequal toxicities of atmospheric pollutants

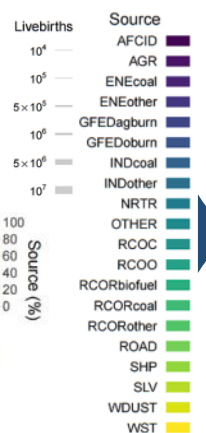
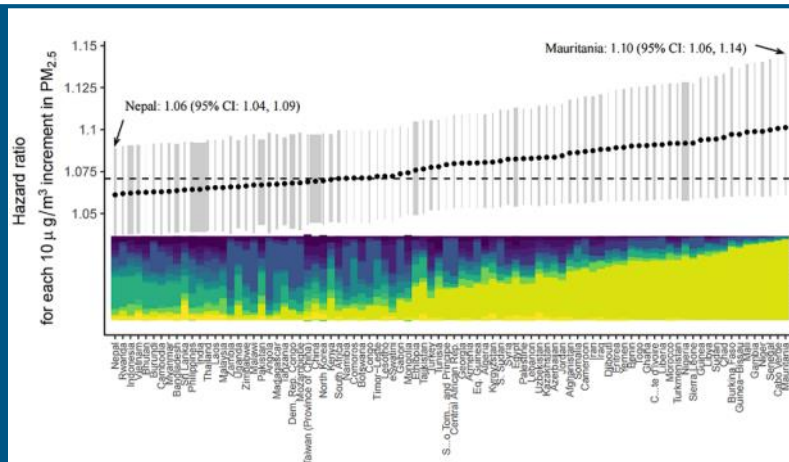
## PM<sub>2.5</sub> is a chemical mixture



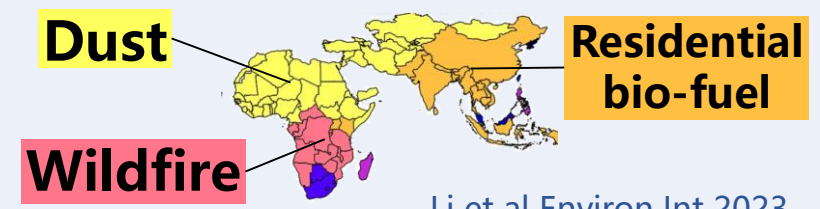
## Differential effects for PM<sub>2.5</sub> components



## Sources underlying burden of PM<sub>2.5</sub>-associated diseases



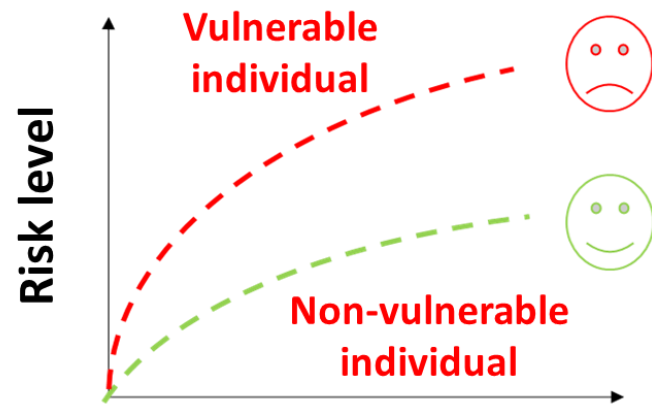
## Leading source underlying PM<sub>2.5</sub>-related child mortality



Li et al Environ Int 2023  
J Hazard Mater 2023  
Ecotoxicol Environ Saf 2023

# Individuals vulnerable to air pollution

## Air pollution vulnerability



Exposure level

Vulnerability: same exposure, more adverse outcome



- Child mortality
- Respiratory infection
- Preterm birth
- Low birthweight
- Stillbirth
- Metabolic disorders
- Aging

## US EPA statements on PM<sub>2.5</sub> vulnerability

Adequate

Suggestive

Inadequate

Evidence Classification	Factor Evaluated	Population/Lifestage Potentially at Increased Risk	Factor-Specific Evidence	Evidence Informing an Increase in Risk
		<p>Section 12.5.1.1</p> <p><b>Child</b></p>	Strong evidence demonstrating health effects in children, particularly from epidemiologic studies of long-term PM <sub>2.5</sub> exposure and impaired lung function growth, decrements in lung function, and asthma development.	Limited evidence from stratified analyses to inform increased risk in children compared to adults. However, evidence from studies of pediatric asthma and impaired lung development provide strong and consistent evidence that effects are observed in children.
		<b>Non-white</b>		Evidence from multiple epidemiologic studies demonstrating higher PM <sub>2.5</sub> exposure in nonwhite populations. Consistent evidence from epidemiologic studies demonstrating increased risk for mortality and cardiovascular/respiratory morbidity.
		<b>Cardiovascular</b>	Causal relationship for PM <sub>2.5</sub> exposure and cardiovascular effects based on CV mortality and morbidities that are plausibly more prevalent in those with pre-existing CV disease/conditions.	Generally supportive evidence from epidemiologic studies demonstrating differential effects for those with hypertension. Limited and inconsistent evidence for other pre-existing cardiovascular diseases.
		<b>Respiratory</b>	Likely to be causal relationship for short-term PM <sub>2.5</sub> exposure and respiratory effects based primarily on evidence for asthma and COPD exacerbation. Evaluated outcomes are often specific to those with asthma or COPD and those without asthma or COPD are not included for comparison.	Limited evidence. Primarily cardiovascular outcomes in epidemiologic studies. Although asthma exacerbation is a key outcome for conclusions on respiratory effects, no evidence demonstrates an increase in risk for those with asthma compared to those without. There is very limited evidence for COPD.
		<b>Obesity</b>		Based primarily on evidence for increased risk for mortality with supporting evidence from studies of subclinical cardiovascular outcomes.
		<b>Genetic mutation</b>	Biological plausibility for PM <sub>2.5</sub> -associated health effects is based on biological pathways including oxidative stress as early biological responses on exposure to PM <sub>2.5</sub> .	Generally consistent evidence for increased risk for respiratory and cardiovascular outcomes for genetic variants in the glutathione transferase pathway, which has an important role in oxidative stress. Limited evidence for other genetic variants.
		<b>Low socioeconomic status</b>		Evidence demonstrates increased exposure and some evidence for stronger associations for mortality with low SES. Comparison across SES metrics are a limitation.
		<b>Current smoking</b>		Based primarily on evidence from long-term exposure studies of lung cancer mortality and incidence, and total mortality report generally consistent evidence of greater risk in individuals who currently smoke or were former smokers compared to never smokers.
		<b>Diabetes</b>		Inconsistent evidence across studies of mortality, cardiovascular morbidity, and inflammation.
		<b>The elderly</b>	Evidence demonstrating health effects in older adults, particularly from short- and long-term PM <sub>2.5</sub> exposure and cardiovascular or respiratory hospital admission, emergency department visits, or mortality.	Inconsistent evidence across a large body of studies with stratified analyses.
		<b>Male</b>	Males: Reproductive factors (e.g., sperm motility). Females: Gestation and birth outcomes.	Inconsistent evidence across studies for mortality and cardiovascular and respiratory effects.
		<b>Urban</b>		Some evidence demonstrates potential for urbanicity to modify PM <sub>2.5</sub> -related health effects, but results are inconsistent across the broad range of metrics used.
		<b>Unhealthy diet</b>		Inconsistent evidence across a limited evidence base.



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# Clean air action in PRC: an quasi-experimental health intervention

# Clean air actions in PRC: 2013 to now

## Air pollution is a common issue

London, UK



Los Angeles, US



Beijing, PRC



New Delhi, India



## Rapidly reduced PM<sub>2.5</sub> pollution

**Bloomberg**

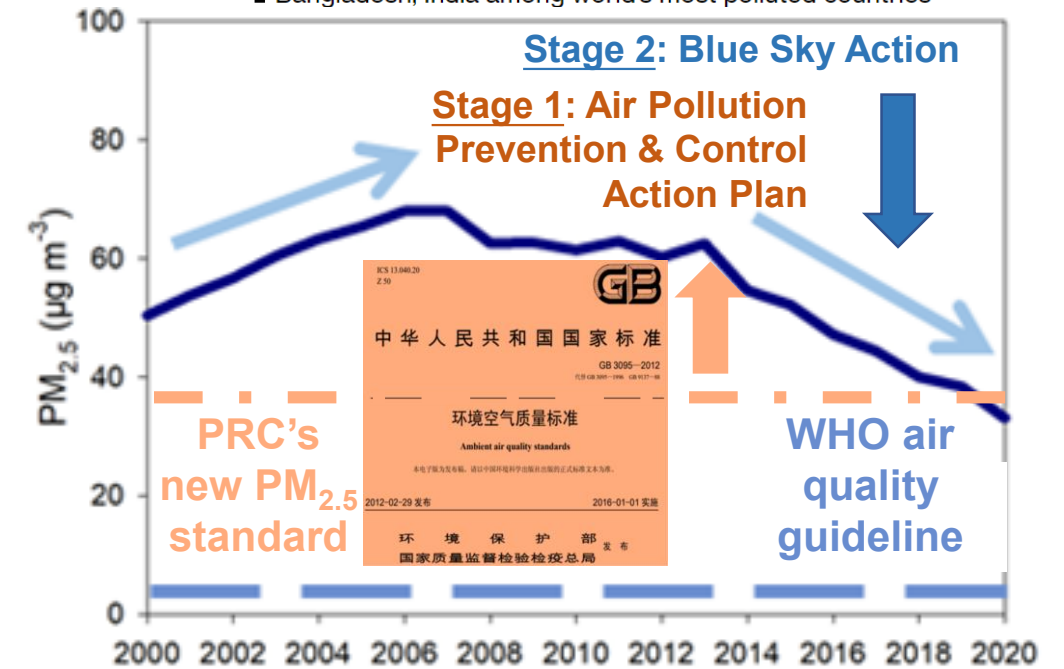
Asia Edition

• Live Now Markets Technology Politics Wealth Pursuits Opinion Businessweek Equality **Green** CityLab

**Green**  
Greener Living

### China Reduced Air Pollution in 7 Years as Much as US Did in Three Decades

- Poor air quality reduces life expectancy more than smoking
- Bangladesh, India among world's most polluted countries

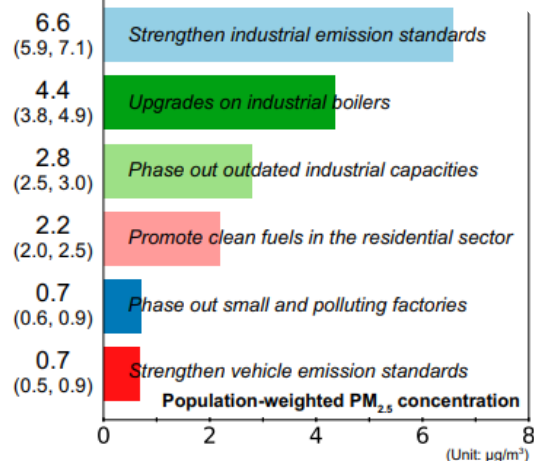
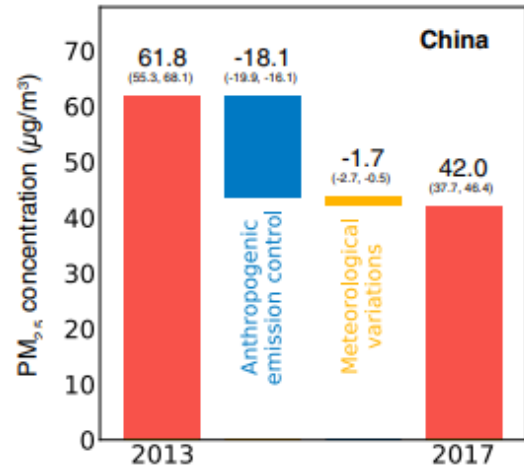


Source: tapdata.org.cn



# Emission-control policies & trends in major air pollutants

## Emission controls

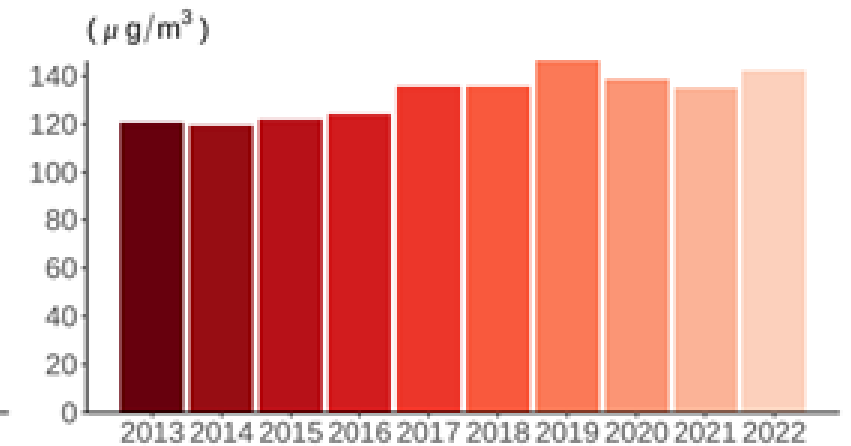


Zhang et al. PNAS 2019

## Trends, 2013-2020

PM<sub>2.5</sub> ↓

O<sub>3</sub> ↑

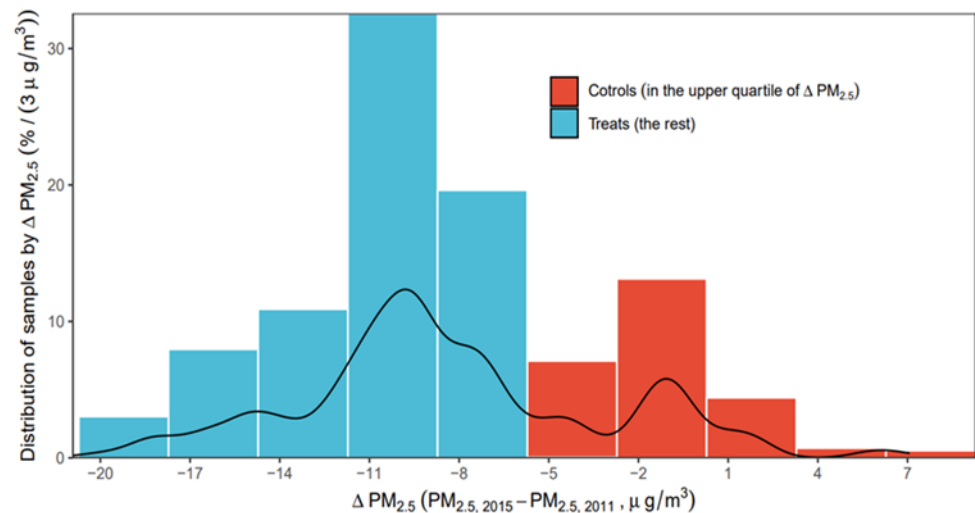


CCAPP report, 2023

# Observed health benefits from clean air intervention

## Quasi-experiment

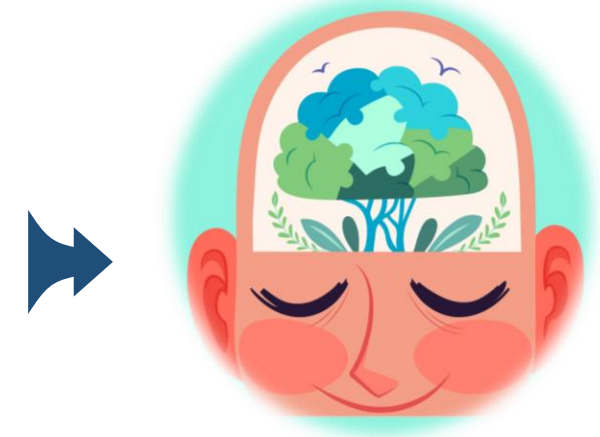
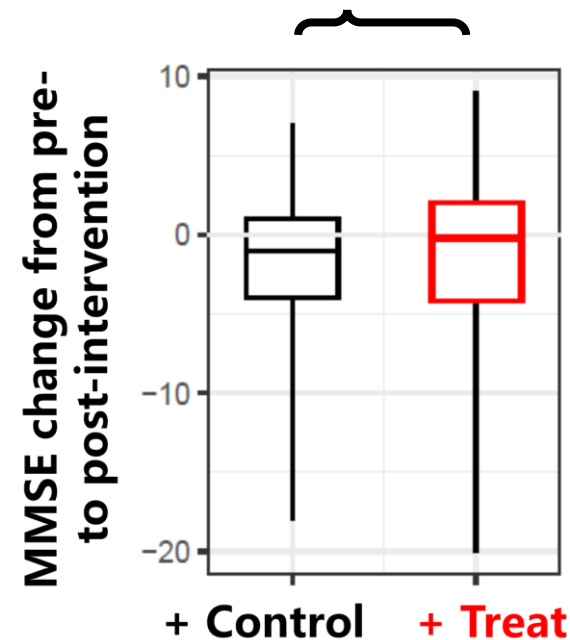
Groups by  $PM_{2.5}$  reduction target or real-world  $PM_{2.5}$  reductions:



**Control  $\leq 5\%$  vs Treat  $> 5\%$**

## Statistical model to show policy effect

e.g., DID model:  
Between-group difference reveals policy effect



**Improved cognitive function**

# Clean air actions improved health in multiple dimensions

- ✓ Improved cognitive function
- ✓ Reduced depressive risk

(Lancet Healthy Longev 2022; Lancet Reg Health West Pac 2021; Nat Commun, 2019)

- ✓ Improved lung function

(Ann Am Thorac Soc 2021)

- ✓ Improved physical mobility

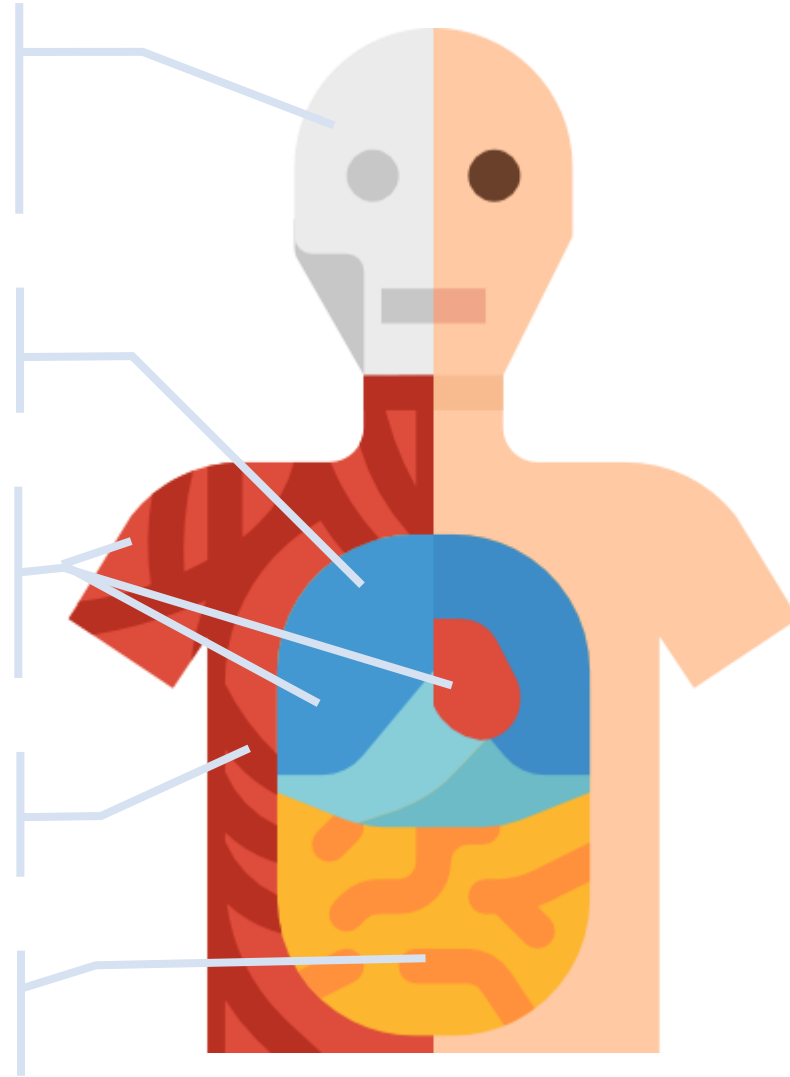
(J Gerontol A 2021)

- ✓ Improved lipid profiles

(Environ Int 2021)

- ✓ Improved kidney filtration

(Health Data Sci 2022)

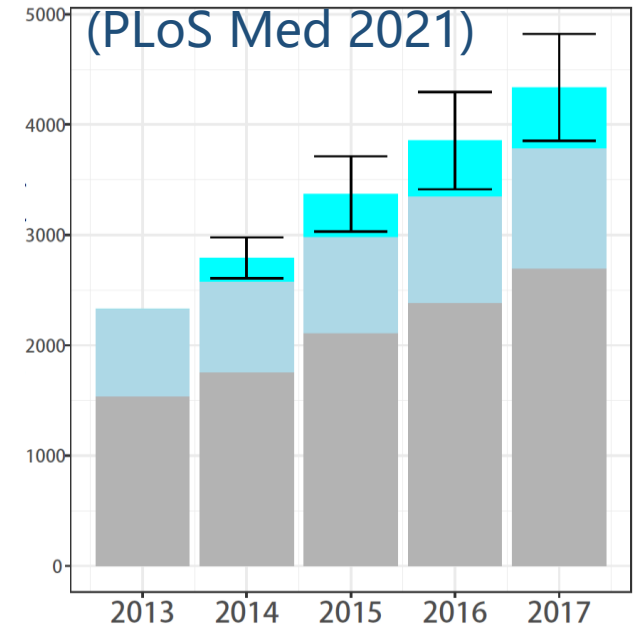


The saved household medical expenditure due to clean air action: **1% GDP**

2013-2017

- Without policy, the increased cost
- Household medical cost
- Public medical cost

Household medical expenditure (RMB per capita)





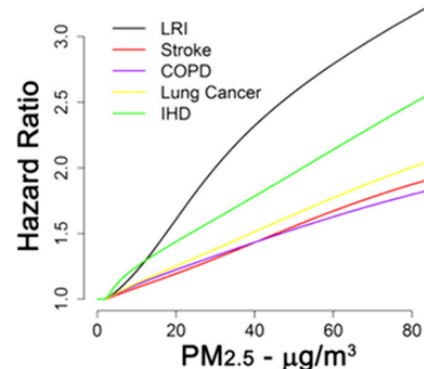
03

# Health impact assessment: enlarged benefits & lowered inequality

# Exposure and health impact assessments

## Health impact assessment model

### Exposure response function

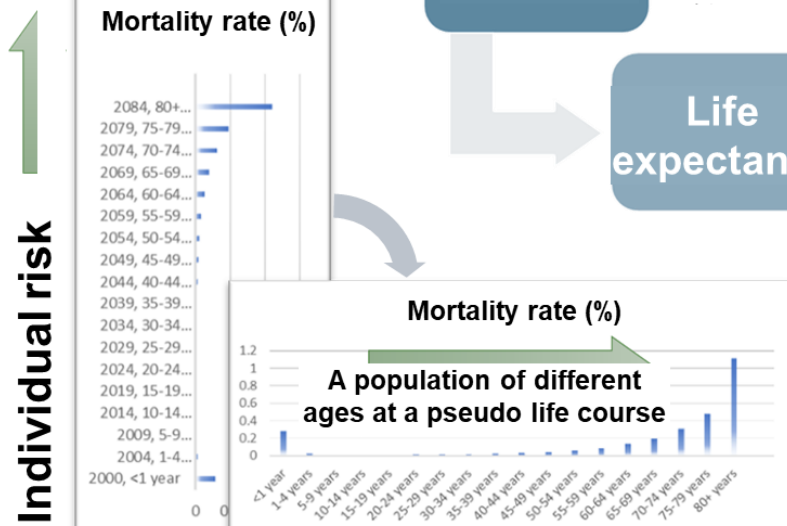


Exposure

Life table

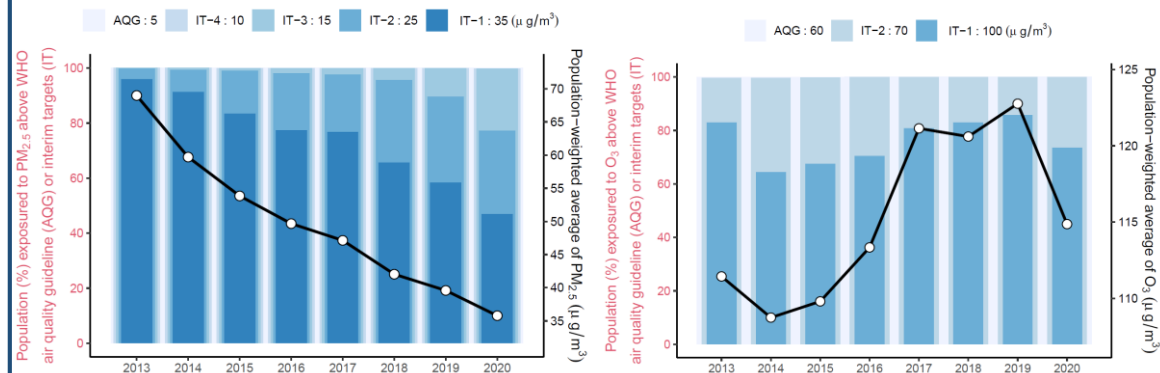
Premature death

Life expectancy

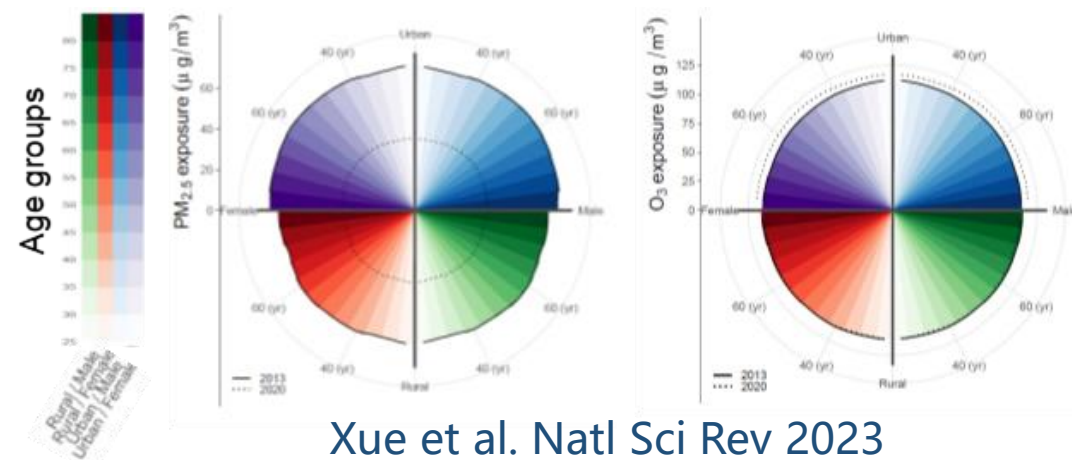


## Average or by subpopulations

### Population-weighted average



### By sex, age and urban/rural residence

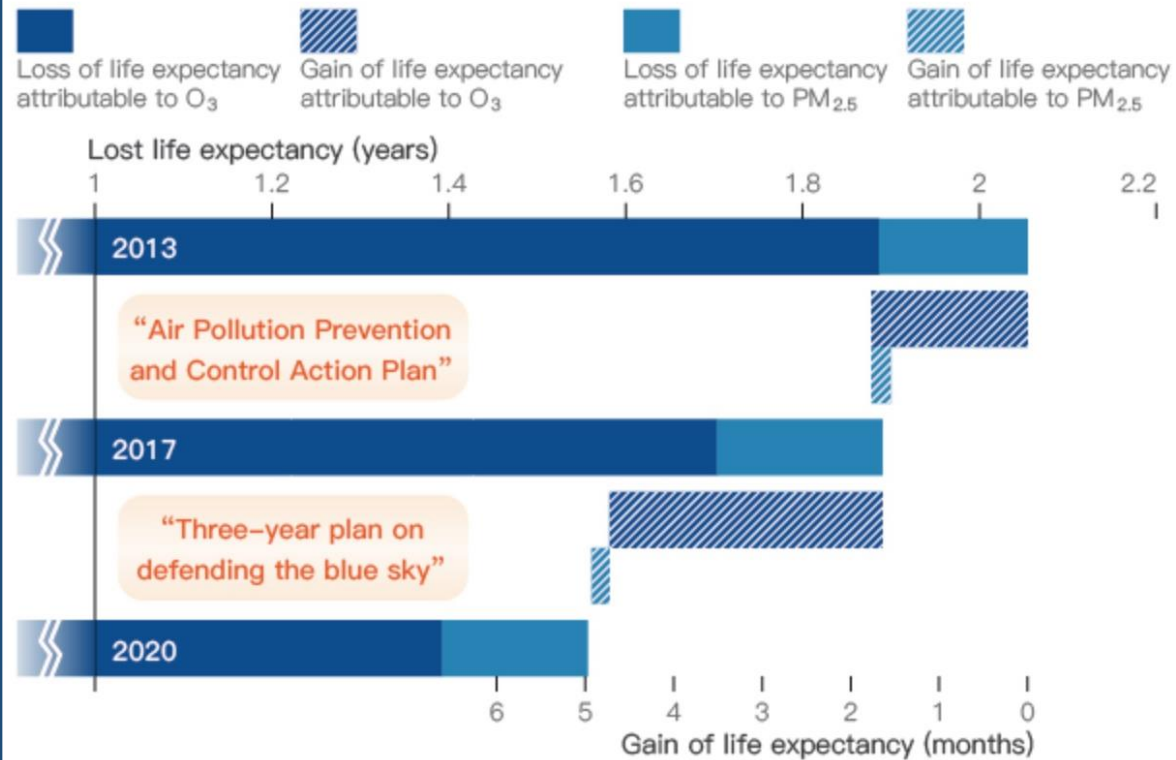


Xue et al. Natl Sci Rev 2023

# Gain of life expectancy due to clean air actions

## Tempora trend

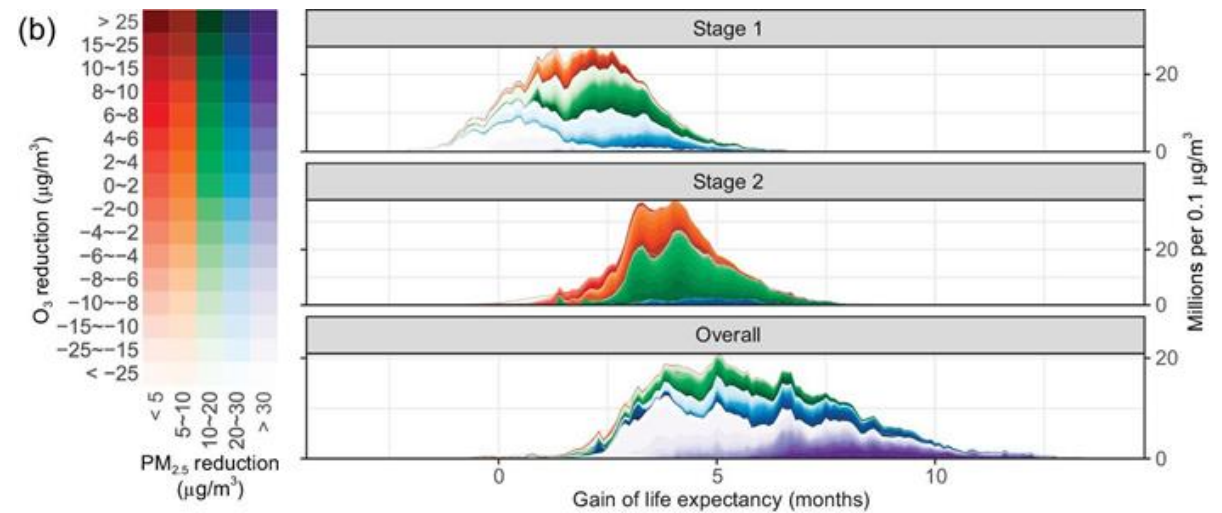
Temporal trend in gain of life expectancy, determined by changes in loss of life expectancy attributable to  $PM_{2.5}$  and  $O_3$  exposure caused by Clean Air Actions in China, 2013-2022.



## Spatial distribution

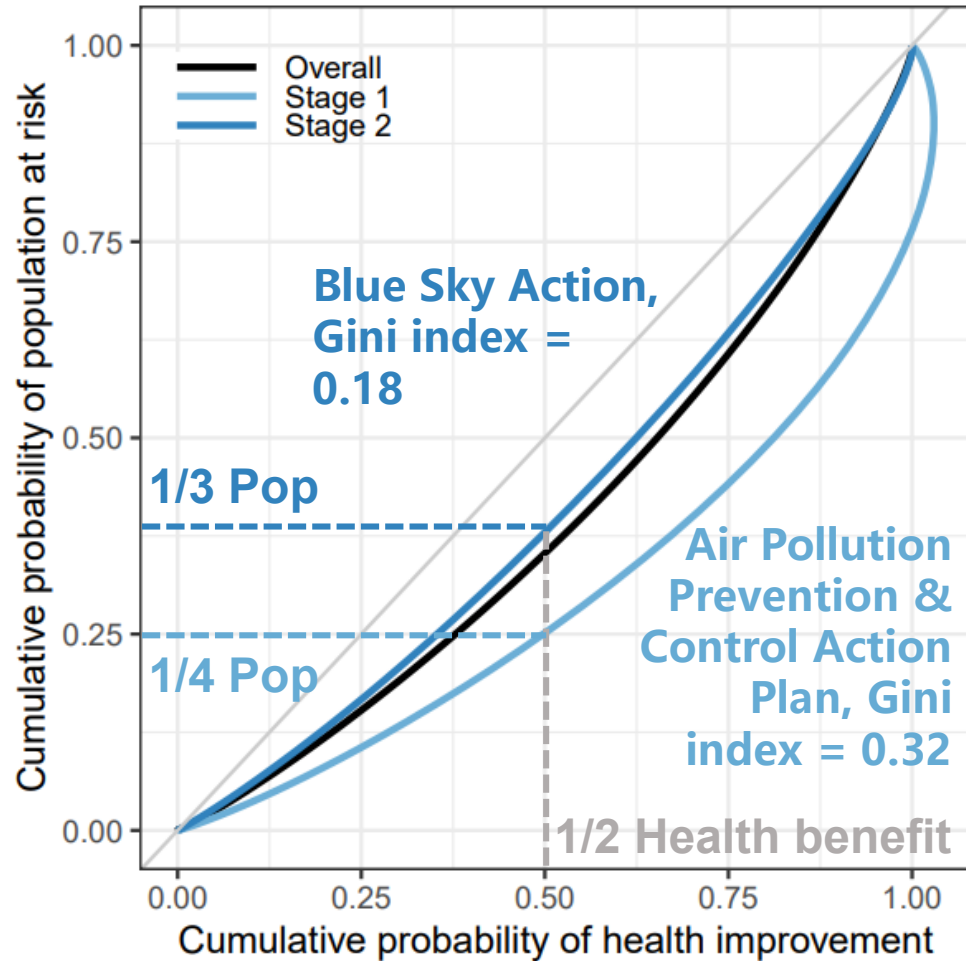
Stage 1: Air Pollution Prevention & Control Action Plan

Stage 2: Blue Sky Action




# Health inequality and progress in PRC's clean air actions

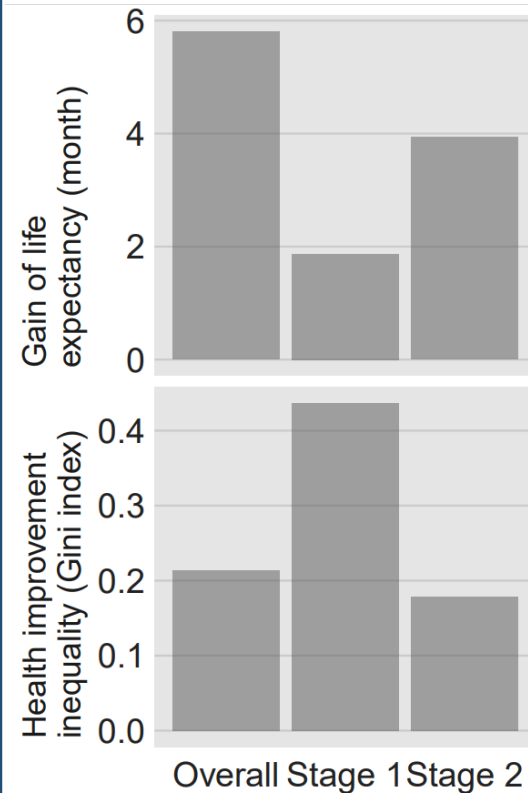
## Distribution of gain of life expectancy



## Efficacy and Equality

**NSR** National Science Review

Health benefits from the rapid reduction in ambient exposure to air pollutants after China's clean air actions: progress in efficacy and geographic equality 





04

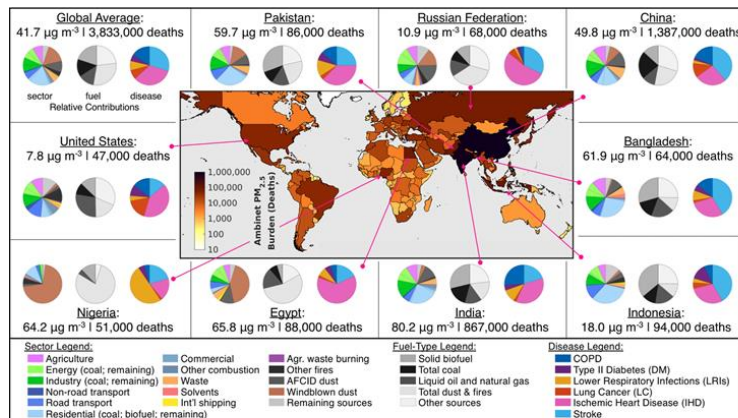
# **Air quality challenges in Asia: Climate-related & anthropogenic pollution**



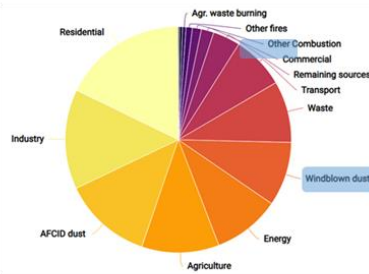
# Air pollution source profile, and disease profile in Asia

## Sources underlying PM<sub>2.5</sub> deaths

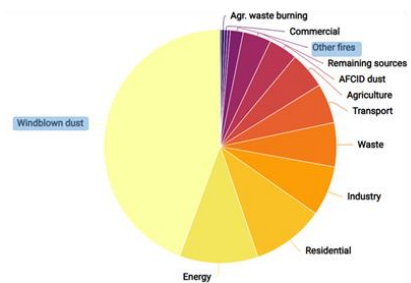
Both anthropogenic and **climate-related sources** contribute to air pollution in Asia



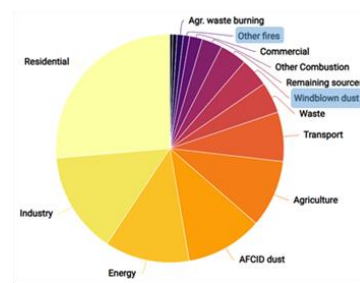
### East Asia



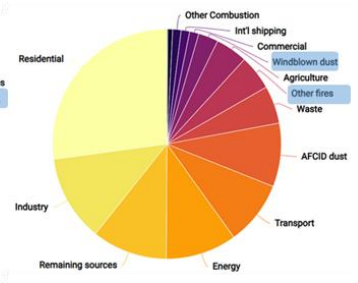
### Central Asia



### South Asia

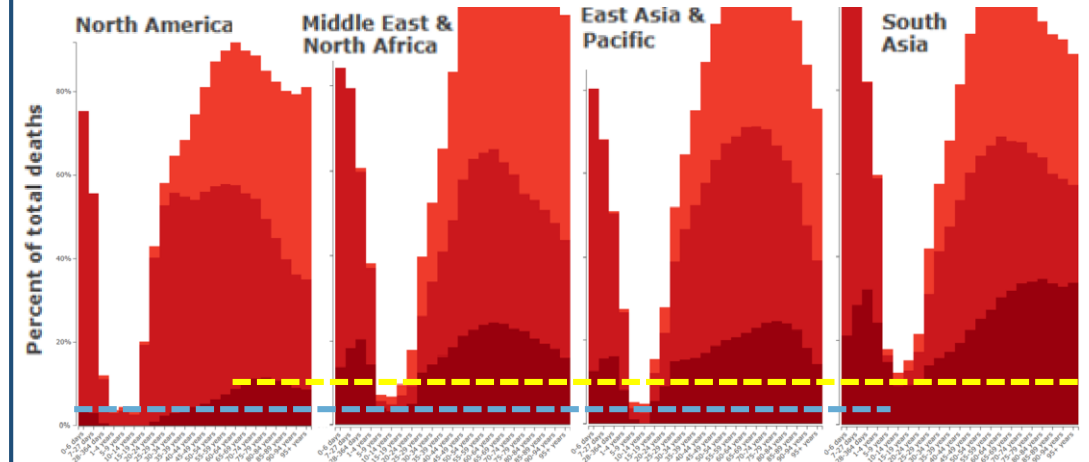


### Southeast Asia



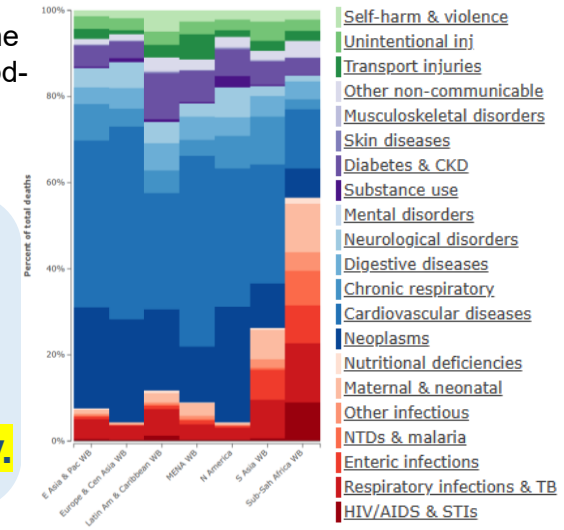
McDuffie et al. Nat Commun 2021

## Profile of diseases in Asia



<https://vizhub.healthdata.org/gbd-compare/>

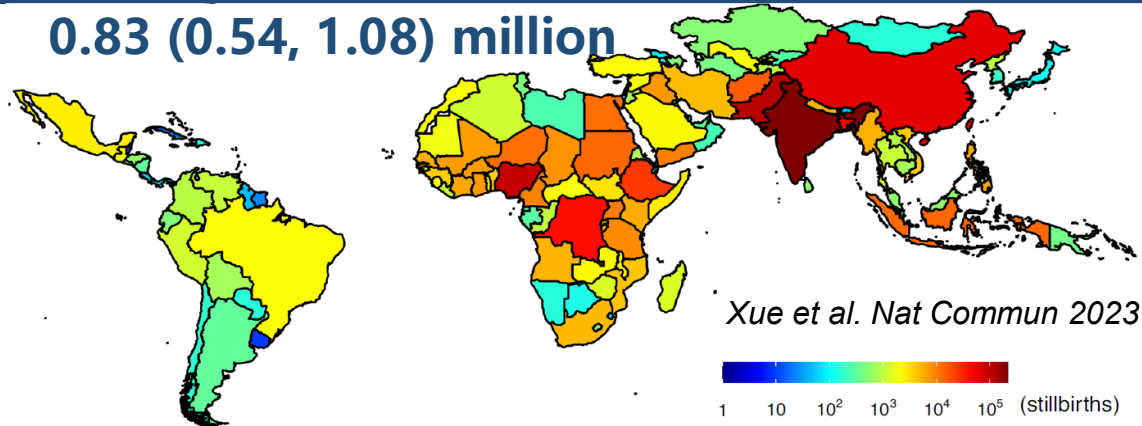
Asia is rich of environment-sensitive diseases, particularly for the vulnerable **children** and **the elderly**.



# Burden of diseases attributable to early-life PM<sub>2.5</sub> exposure

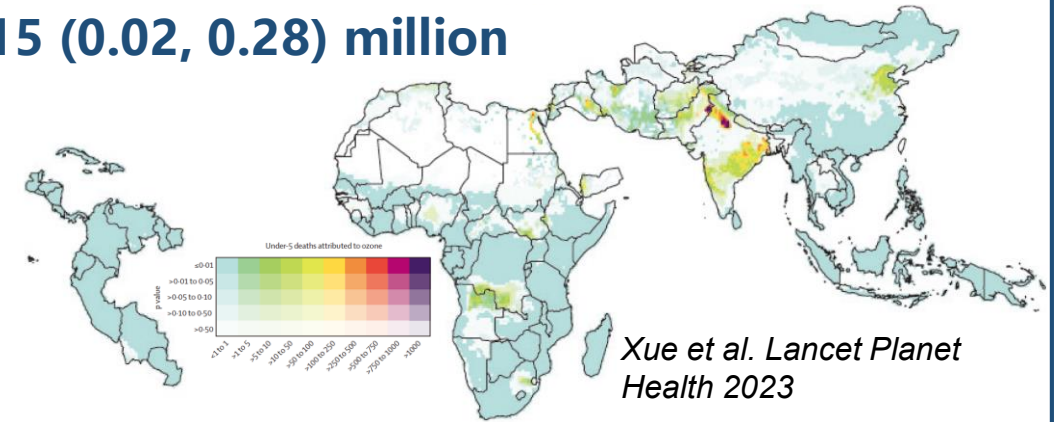
## PM<sub>2.5</sub>-related stillbirths

0.83 (0.54, 1.08) million



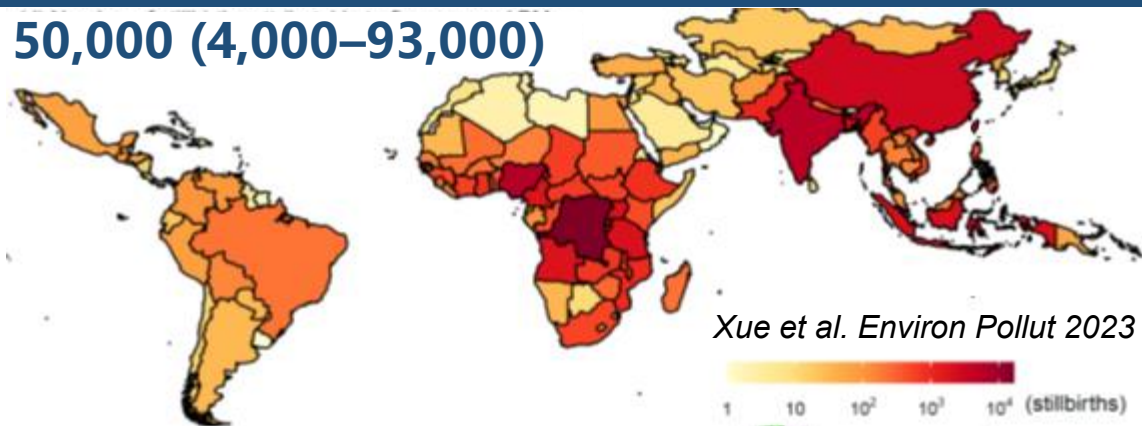
## O<sub>3</sub>-related child mortality

0.15 (0.02, 0.28) million



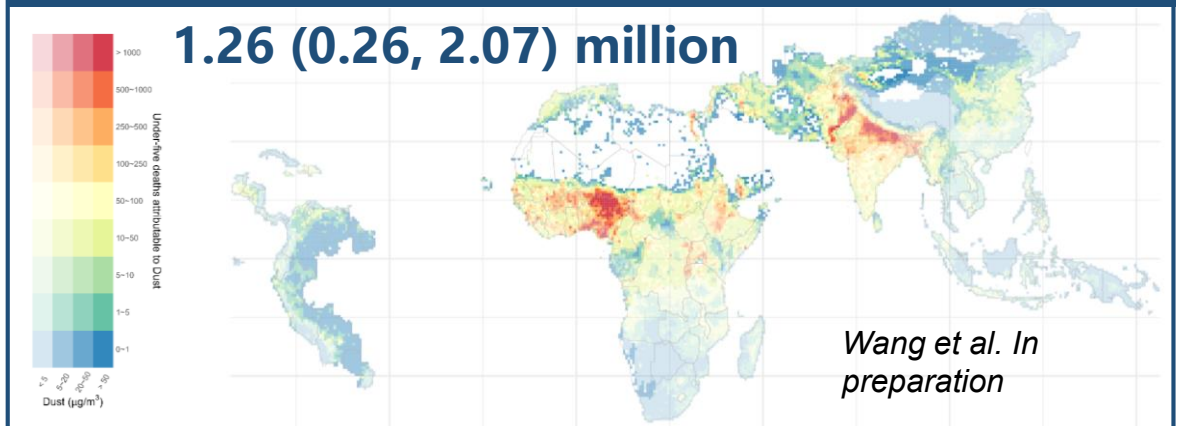
## Wildfire-related stillbirths

50,000 (4,000–93,000)



## Dust-related child mortality

1.26 (0.26, 2.07) million



# Atlas for Burden of Climate-related Diseases due to Early-life Environmental Exposures (ABCDE<sup>3</sup>)

	Neonatal death or its mediators		Child death or its mediators		
	Stillbirth	Neonatal deaths	Birthweight	Child deaths	Acute respiratory infection (ARI)
<b>Temperature</b>	<b>Kang:</b> 3613 deaths/yr (SSP245, 2021-30)	<b>GBD:</b> 893 deaths/yr (2015)		<b>GBD:</b> 1004 deaths/yr (2015)	
<b>O<sub>3</sub></b>			<b>Tong:</b> Reduced birthweight of 41g (2015)	<b>Xue:</b> 2600 deaths/yr (2015)	
<b>Dust PM<sub>2.5</sub></b>	<b>Xue:</b> 20595 deaths/yr (2015)			<b>Wang:</b> 19764 deaths/yr (2015)	<b>Lu:</b> 4100 children/yr (2015)
<b>Fire PM<sub>2.5</sub></b>	<b>Xue:</b> 2795 deaths/yr (2015)		<b>Li:</b> Reduced birthweight of 14 g, Mediated 841 deaths/yr (2000-14)	<b>Xue:</b> 19055 deaths/yr (2015)	
<b>Total PM<sub>2.5</sub></b>	<b>Xue:</b> 63830 deaths/yr (2015)	<b>GBD:</b> 7729 deaths/yr (2015)	<b>GBD:</b> Reduced birthweight of 22 g, Shortened gestation of 1 week	<b>GBD:</b> 4564 deaths/yr	<b>GBD:</b> 17642 children/yr (2015)

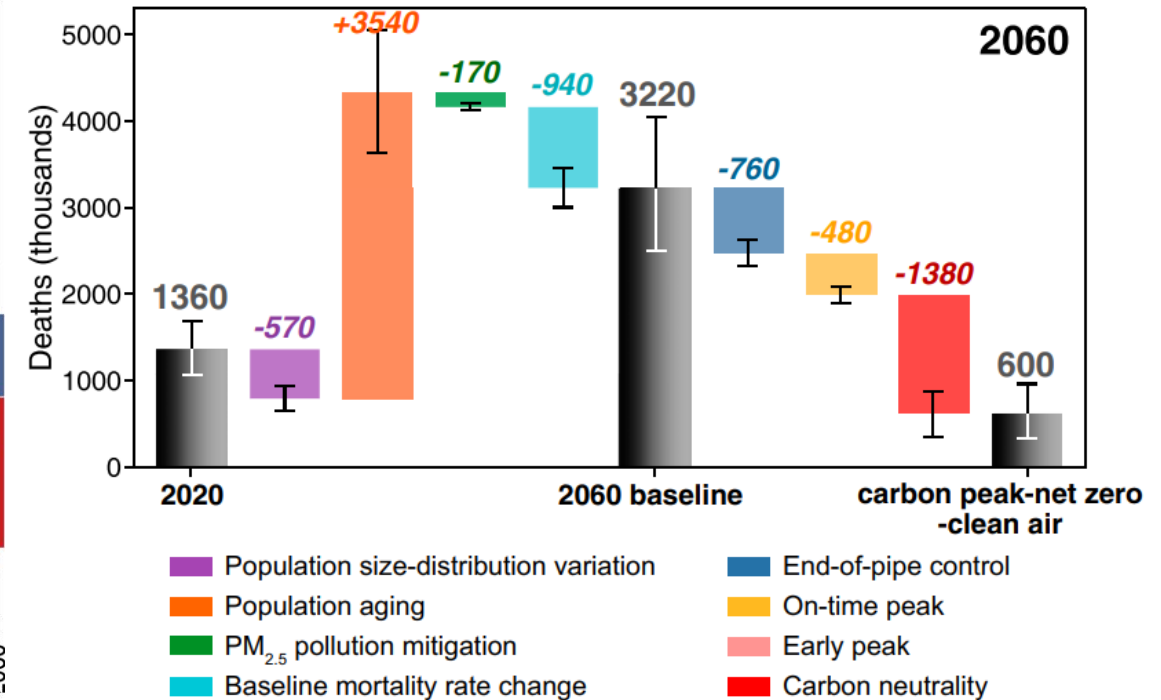
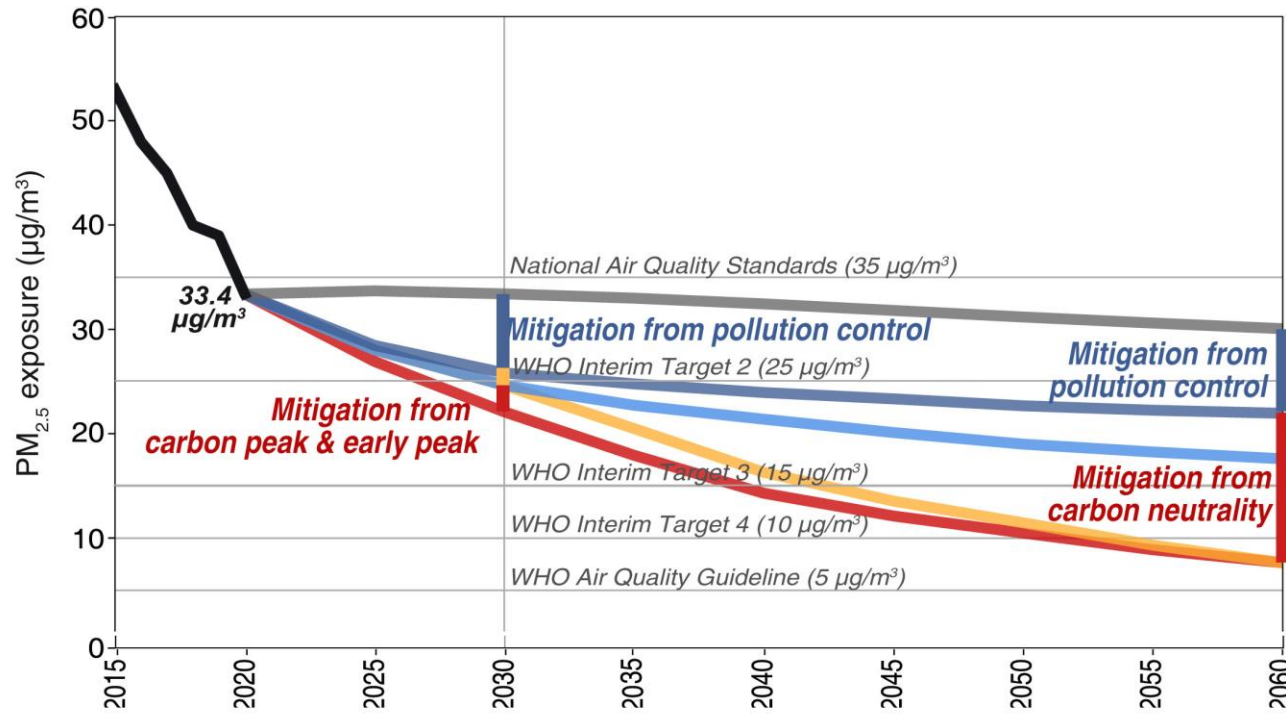
*The pilot ABCDE<sup>3</sup> project for PR China*

GBD results

Our findings

# Carbon Neutrality: an opportunity to remove air pollution

- On-time carbon peak can avoid 480,000 premature deaths per year
- Carbon neutrality can further avoid 1380,000 premature deaths per year
- With carbon neutrality, PM<sub>2.5</sub> can meet WHO interim target 4



# Summary

## Clean air actions in PRC

The clean air actions can be an effective public health intervention with universal coverage, and thus promote health equality.

## Air quality challenges in Asia

(1) More anthropogenic emissions, (2) climate change and (3) increased human vulnerability can bring a heavier burden of air pollution. Achieving carbon neutrality is one possible solution.

# Thank you for attentions

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